International Journal of Mechanical and Production
Engineering Research and Development (IJMPERD)
ISSN (P): 2249-6890; ISSN (E): 2249-8001
Vol. 7, Issue 6, Dec 2017, 179-186

EFFECT OF CHROMIUM ON TENSILE AND FATIGUE BEHAVIOUR OF COPPER NICKEL SPINODAL ALLOY

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Original Article

ABSTRACT

This paper considers the construction of a CU-Ni-Cr Spinodal alloy. The objective of the work is, to prepare an alloy with commercially best composition and treated it with spinodal decomposition, and to study the effect of Chromium on Tensile and Fatigue behaviour of it. To analyze spinodally decomposed product Optical and transmission electron microscopic revision, have been undertaken. Homogenized and solution treated specimens, were aged at various temperatures for different period of time. Aged specimens were tested for tensile and fatigue behaviour. Tensile stresses are related to the hardness of the alloy and fatigue, is weakening of the alloy result of stresses developed, due to cyclic load. The correlation of mechanical properties with microstructure, then demonstrates a dependence of yield stress growth on lattice parameter change, between the two phases. The addition of Cr resulted, in an increase in ultimate tensile strength, proportional limit stress and fatigue strength, over the Cr-free alloy. The results obtained by calculation and experimentally showed, a good agreement.

KEYWORDS: Cu-Ni-Cr Spinodal Alloy, Heat Treatment, Tensile Test & Fatigue Test

Received: Sep 27, 2017; **Accepted:** Oct 18, 2017; **Published:** Nov 07, 2017; **Paper Id.:** IJMPERDDEC201719

INTRODUCTION

The intention of this research is, to investigate the changes in microstructure, during spinodal decomposition of Cu-Ni-Cr alloy, also study the effect of chromium on Mechanical properties of Cu-Ni alloy. Cu-Ni alloy was intestinally chosen, due to its commercial importance as an alloy of excellent strength. Various researches were carried out on these alloys, in order to improve their mechanical properties. The Cu-Ni binary system is measured, to be an ideal isomorphous system. Whereas, the addition of a ternary alloying element, such as Cr will introduces miscibility gaps and it changes the properties of the binary alloys. The miscibility gap in the Cu-Ni-Cr system was first reported by Meijering et al, by means of metallographic and X-ray diffraction methods at 930°C an isothermal section was determined in ″Figure 1″.

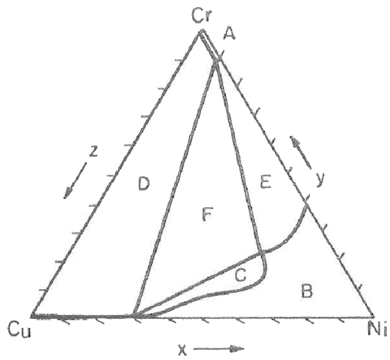

Figure 1. Cu-Ni-Cr Ternary Phase Diagram At 930°C. Atomic Concentrations- A: Homogeneous B.C.C.; B: Homogeneous F.C.C.; C: 2 F.C.C. Phases; D: B.C.C. and Cu-Rich F.C.C.; E: B.C.C. and Ni-Rich F.C.C.; F: B.C.C. and 2 F.C.C. Phases

Properties of any material are decided by the microstructure of that material. With the change in microstructure of an alloy, will have significant effect on its properties. Spinodal decomposition produces modulated and ordered microstructure, during aging treatment. It will improve the strength of the spinodally decomposable alloys [1].

Hillert [8, 9], was the first to show, on the basis of a one-dimensional model, that when an alloy is inside the spinodal region of the phase diagram modulated structures can be formed. Cahn [10, 11], developed a more general linear model, applicable in three dimensions. It refers to a method in which, a supersaturated solid solution decomposes into solute-rich and solute-lean regions, when it is aged at a suitable temperature [13]. The strain field around the modulated structure, formed by spinodal decomposition, along with the ordered structure impedes the dislocation motion and thereby, causes hardening to occur [15]. However, very few systematic studies of other systems have been performed, to examine the relationship of mechanical properties, with the microstructural parameters of spinodal alloys [14]. Therefore, it is the intention of this research, to investigate these parameters and to establish these relationships in a commercial Cu-Ni-Cr alloy.

EXPERIMENTAL PROCEDURES

THE SAMPLE

The required alloy sample elements were procured, in the commercial market in pure form. The sample is a commercial Cu-based alloy of following composition by weight %:

Cu - balance C - 0.014%,

Ni - 28.9% Ti - 0.051%

Cr - 2.84% Si - 0.091%

Mn - 0.55% Fe - 0.32%

Zr - 0.22%

HEAT TREATMENT

The alloy was placed in an electric arc furnace, with an inert atmosphere; Aragon was supplied during the heat treatment. The temperature within the hot zone of the furnace, was controlled to an accuracy of ± 5%. The alloy was

homogenized and solution heat treated at 1100°C. Further, the solution heat treated alloys were aged for 72 hours. Alloys then quenched into brine solution. In order to avoid oxidation of the alloy, inert atmosphere was used during the entire heat treatment processes. After cutting and machining, the various experimental specimens were annealed in quartz tubes, filled with purified argon at 1100°C, for two hours and quenched again in ice brine. The microscopic examinations were conducted, using Carl-Zeiss metallurgical microscope.

TENSILE TEST

For tensile test specimens, the alloy was first cut into round bars and the heat-treatment subsequently performed. The round bars, were then machined into standard tensile specimens.

The specimens were tensile pulled, in a Computerised Universal Testing machine "Figure 2″.

Figure 2: Computerised Universal Testing Machine

FATIGUE TEST

For fatigue test specimens, cylindrical axial specimens machined, from the rectangular blanks. The specimens had to an overall length of 75 mm, gage length of 20 mm, and gage diameter of 4.75 mm [6].

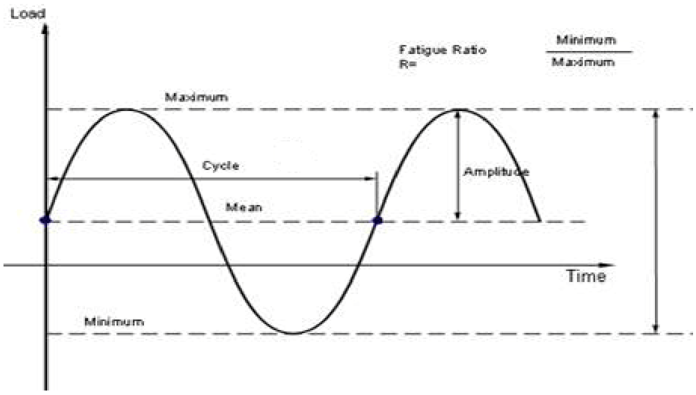

Figure 3: Cyclic Load Vs Time Graph

The specimens were tested for fatigue behaviour, in a Fatigue tester "Figure 4″.

Figure 4: Fatigue Tester (Source: SOM Lab. IIT Guwahati)

RESULTS AND DISCUSSIONS

The tensile behaviour of the alloys, was greatly influenced by the presence of Cr ″Table 1″. The higher tensile strength in Cu-Ni-Cr is because of presence of Cr in Cu-Ni binary system, which is effective in increasing the resistance to dislocation motion and increasing the work-hardening rate of the alloy. From the graph "Figure 5″, it becomes clear that Cu-Ni-Cr exhibits the higher strength and work hardening rate, than Cu-Ni. This indicates, with the addition of Cr in Cu-Ni alloy tensile behaviour of alloy will increases. The Cr containing alloy, exhibited higher ultimate tensile strength "Figure 6″.

Table 1: Tensile Behaviour of Cu-Ni and Cu-Ni-Cr Spinodal Alloy

Alloy	Young's Modulus (GPa)	Proportional Limit Stress (MPa)	Ultimate Tensile Strength (MPa)	Strain-to-Failure (%)
Cu-Ni	135	221	797	1.91
Cu-Ni-Cr Spinodal	139	252	903	0.98

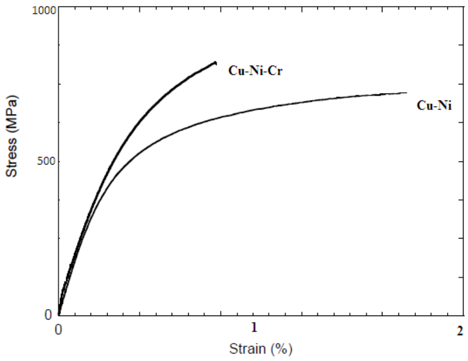

Figure 5: Tensile Behaviour of Cu-Ni-Cr and Cu-Ni Alloys

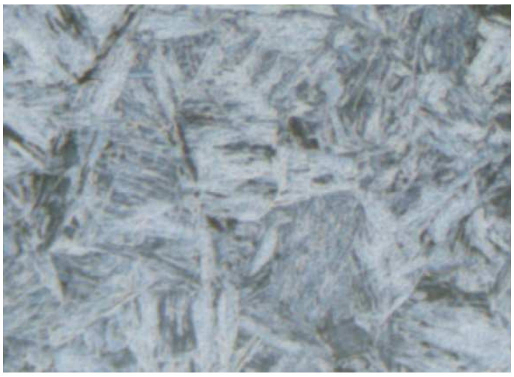

Figure 6: Microstructure of Cu-Ni-Cr Alloy Indicates Higher Tensile Behaviour

The fatigue behaviour of the alloys was greatly influenced by the presence of Cr ″Table 2″. The addition of Cr, significantly increased fatigue resistance. The proportional limit stress, is a very good pointer of the beginning of plasticity "Figure 7″. In fatigue loading, this damage is managing the fatigue life, that takes place, close to the ultimate tensile strength. Thus, the proportional limit stress may be a much better indicator of the fatigue strength, than ultimate tensile strength.

Table 2: Fatigue Behaviour of Cu-Ni and Cu-Ni-Cr Spinodal Alloy

Alloy	Proportional Limit Stress (MPa)	Ultimate Tensile Strength (MPa)	Fatigue Strength (MPa)
Cu-Ni	221	797	170
Cu-Ni-Cr Spinodal	252	903	178

Figure 7: Microstructure of Cu-Ni-Cr Alloy Indicates Higher Fatigue Behaviour

CONCLUSIONS

The mechanical behaviour of Cu- Ni was investigated. In exacting, the effect of Cr with spinodal decomposition, on tensile and fatigue behavior was studied, yielding the following conclusions:

- The addition of spinodal Cr resulted in an increase in proportional limit stress and ultimate tensile strength, over the Cu-Ni alloy.

- Cu-Ni-Cr spinodal alloy had a higher fatigue resistance, than the Cu-Ni alloy. The higher fatigue resistance can be recognized, to the enhanced fatigue strength.
- The yield stress increased rapidly, during the early stages of ageing.
- The decrease in yield stress of Cu-Ni-Cr alloy occurred, when the particles began to drop coherency.
- The yield stress increases as aging time increases.
- The alloy demonstrates morphological character, such as aligned precipitates and absence of preferential precipitations at microstructural, in-homogeneities.

ACKNOWLEDGEMENTS

The authors are grateful to Heads & associates of Research lab, Mechanical Engineering Department, Engineering Metallurgy laboratory, JD Institute of Engineering & Technology, Yavatmal (MS), India to carry out the present work.

REFERENCES

1. *Polasik, S.J., J.J. et al, (2002), Fatigue crack initiation and propagation of binder-treated powder metallurgy steels. Metall. Mater. Trans. A, Vol.33, No.1, 73-81.*
2. *Christian, K.D. & German, R.M., (1995). Relation Between Pore Structure and Fatigue Behavior in Sintered Iron-Copper-Carbon. Int. J. Powder Metall., Vol.31, No.1,51-61.*
3. *Carabajar, S., et al, (1998). Fatigue Behavior of a Nickel Alloyed Sintered Steel. Mater. Sci. Eng., Vol. A 257, 225-234.*
4. *Yokoi, T., et al, (2001). Cyclic Stress Response and Fatigue Behavior of Cu Added Ferritic Steels. J. Mater. Sci., Vol.36, 5757-5765.*
5. *Sudhakar, K.V., (2000). Fatigue Behavior of a High Density Powder Metallurgy Steel, Int. J. Fatigue, Vol.22, 729-734.*
6. *Chawla, N., et al, (2002). Effect Of Copper And Nickel Alloying Additions On The Tensile And Fatigue Behavior Of Sintered Steels. Adv Powder Metall Part Matter, 5, 104.*
7. *Kato, M. & Schwartz, L.H., (1979). The Temperature Dependence of Yield Stress and Work Hardening in Spinodally Decomposed Cu-10Ni-6Sn Alloy. Materials Science and Engineering, 41(1), 137-142.*
8. *Hillert, M., (1956). Thesis MIT.*
9. *Hillert, M., (1961). Acta Metall., 9, 525-535.*
10. *Cahn, J.W., (1961). Acta Metall., 9, 795-801.*
11. *Cahn, J.W., (1962a). Acta Metall., 10, 179-183.*
12. *Baburaj, E. G., et al, (1979). Initial stages of decomposition in Cu-9Ni-6Sn, Journal of Applied Crystallography. 12(5), 476-480.*
13. *Chou, A., et al, (1978). Microstructural Behaviour and Mechanical Hardening in a Cu-Ni-Cr Alloy. J. Mater. Sci., 13, 541-552, CrossRef.*
14. *Ilangovan, S., & Sellamuthu, R., (2016). Measurement Of The Variation Of Mechanical Properties With Aging Temperatures For Sand Cast Cu-5ni-5sn Alloy. Journal of Engineering Science and Technology, 11(11), 1609 – 1619 © School of Engineering, Taylor's University.*

15. *Findik, F. & Rehman, F., (1993). A Spinodal Cu-Ni-Cr alloy. Transactions on Engineering Sciences 2, WIT Press, 219-228.*
16. *Rao, P. P., et al, (1991). Comparative-study of spinodal decomposition in symmetrical and asymmetric Cu-Ni-Cr alloys. J. Mater Sci., 26, 1485-1496.*
17. *F. Findik, 1992, Precipitation reactions in some Cu-Ni-Cr alloys, PhD Thesis, Imperial College, University of London, UK.*
18. *Jappes, J.T., et al, (2006). A text book of Engineering Materials and Metallurgy. Laxmi Publications (P) Ltd., 131.*
19. *Copper-Nickel Alloys, Properties and Applications, published by copper development association TN30, (1982). 1-36.*
20. *Jirapure, S.C. & Dr. Borade, A.B., (2014). A New Approach of Strengthening- Spinodal Decomposition. Int. Journal of Applied Sciences and Engineering Research, Vol. 3 (5), 1021-1029.*
21. *Jirapure, S.C. & Dr. Borade, A.B., (2017). Measurement of Mechanical Properties and Microstructure of Cu-Ni-Cr Spinodal alloy. International Journal of Advanced engineering and Management, Vol.2(3), 78-81.*